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METHOD AND COST OF DREDGING SAND AND GRAVEL, PORTLAND GRAVEL CO., PORTLAND, OREG.[1]

By Howard F. Puariea[2]

INTRODUCTION

This paper is one of a series describing methods and costs of recovering sand and gravel from alluvial deposits in the United States and deals directly with the methods employed by the Portland Gravel Co. in operating a clamshell dredge on the Willamette River near Portland, Oreg., and a pump dredge on the Columbia River near Vancouver, Wash.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local expenditures only and not total production costs. It is recognized that publication of total costs may in some instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations shall ensue.

HISTORY

The Portland Gravel Co. was organized on March 20, 1925, and at once started construction of the clamshell dredge "Boulder" from designs by H. P. Warren and the writer. This dredge was put in operation on the Willamette River near Portland, Oreg., in July, 1925. Few alterations were necessary and the dredge has been in almost constant operation since that time. On May 1, 1926, the company purchased the pump dredge "Sandy" from the Columbia Sand Co. This dredge was designed and built in May, 1924, by the writer. With this equipment the Portland Gravel Co. had the largest capacity in the Portland district and during 1926, 1927, and 1928 furnished sand and gravel for all the major work in the vicinity and in addition supplied customers at Astoria, Oreg., and Longview, Wash. The purpose of the company is to wholesale material delivered on customer's barges alongside the company's dredges. No attempt has ever been made to enter the retail business.

GEOLOGY

The gravel used in the Portland district comes mostly from the bed of the Willamette River near the city of Portland. Outlying districts are supplied partly by material from dry pits and banks. The gravel is found in the river bars containing sand, gravel, silt, and débris. In the part of the river near Portland the bars shift but little due to the narrow channel and reefs of solid rock which protect the head of the bars. Many of these gravel bars contain water-soaked chips deposited in the river by the paper mills at Oregon City 12

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S Bureau of Mines Information Circular 6626."

[2] - One of the consulting engineers, U. S. Bureau of Mines, and president of the Portland Gravel Co.

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miles upstream. When these chips occur in quantity they ruin the deposits because they can not be separated economically; bars containing them are avoided by moving the dredge unless there is a market for fill material which can be loaded directly into barges and not run through the plant. In workable bars the upper gravel to a depth of 10 to 15 feet generally contains driftwood and débris but can usually be run through the plant without ruining the product. Beyond this depth the deposits are exceptionally clean.

The gravel ranges in size from pea gravel to bowlders 8 to 10 inches in diameter, and is mostly loose, although there are sections of hardpan and cemented gravel which are avoided if possible when dredging. The gravel is largely basalt and is hard and sharp. There are sections in the river that contain a high percentage of decomposed or rotten rock that when mixed with the good gravel spoils it for anything but fill.

The sand consists largely of rounded particles of basaltic material and rarely contains more than 10 or 15 per cent of quartz.

DREDGING CONDITIONS

Near Portland the river deposits have been reworked many times and prior to 1921 most of the dredges dumped the bowlders and excess sand back into the river. This refuse practically covers the bars and makes dredging difficult. Since 1921 Government engineers have required all dredges to crush the oversize or move it ashore. Excess sand is still wasted and causes considerable trouble.

The sand as taken from the river is dirty and contains up to 25 per cent of excess fines. In order to build up or properly grade this material it is necessary to waste these fines and to add the coarse material obtained from the crusher fines. The crusher makes about 25 per cent of fines below 3/8 inch so there is plenty of this material to add to the sand. The prepared sand weighs about 2,600 pounds per cubic yard and is so harsh that it requires much more work to put in place than Columbia River sand, although it is stronger.

When sand is saved, about 15 to 18 per cent of the material dug is wasted back to the river. When wasting sand, this proportion increases to about 40 per cent. On an average about 30 per cent of the finished gravel is crushed material.

The river is full of old snags and buried trees which would prove disastrous to a ladder dredge. With the clamshell dredge it is possible to dig around these obstructions. During the freshet period in winter, dredging is further complicated by swift water and drift which fills the excavation with trash and drifting waste sand.

CHOICE OF METHOD

A clamshell dredge was selected as being the cheapest means of recovering the gravel. The decision was based upon the volume needed, the conditions in the river bed, and the great depth of the deposits from which a suction or ladder dredge could not recover material economically.

PROSPECTING AND SAMPLING

Prospecting is done by moving the dredge from one bar to another. In some of the bars the material is fine and in others coarse. The different sizes of gravel are run through the dredge, finished, and samples taken and put through sieve tests. If necessary, changes are made in the screens to grade the gravel to meet specifications. The average weight of the gravel as prepared for market is 2,850 pounds per cubic yard. There has never been any

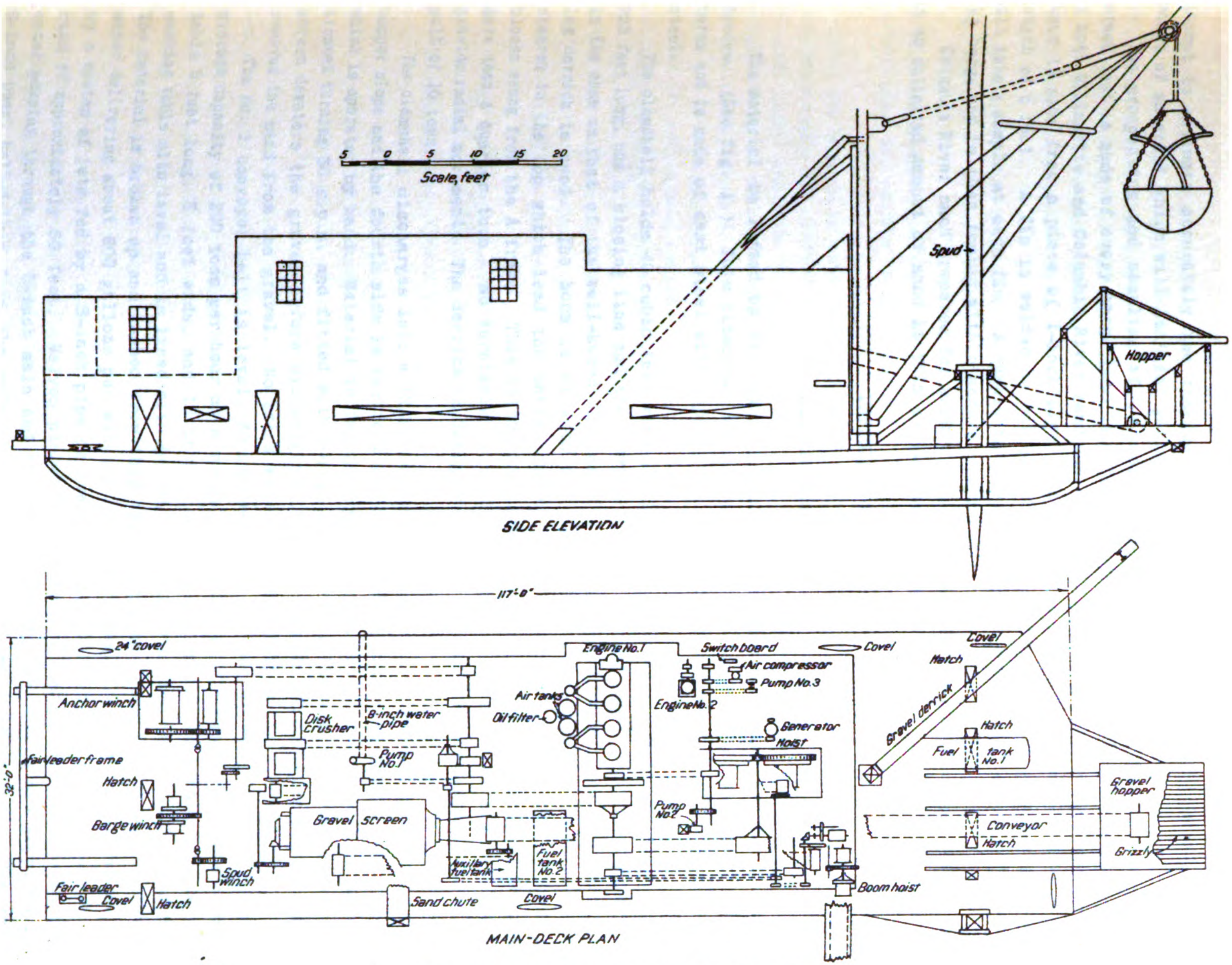


Figure 1.- Side elevation and main-deck plan of dredge "Boulder"

attempt to estimate accurately the reserve in these river bars as there is an unlimited amount of material which will last for years to come.

The prospecting and sampling of Columbia River sand is handled in the same way. A screen test is made of every barge load to determine the fineness modulus. The sand samples of both Willamette and Columbia River sand are taken from the barge with a sand augur. This augur is made from a piece of 1-inch pipe with slots cut in it at 6-inch intervals for a length of 5 feet. A fin is welded on one edge of each slot so that in turning the pipe it will take a sample at each fin. A sample is obtained in this manner at every few feet across the barge and is then tested with standard sieves.

Columbia River sand prepared for market will average 2,250 pounds per cubic yard. There is an unlimited amount of sand in this section of the river.

DREDGING GRAVEL

Dredge "Boulder"

The material is lifted by the clamshell to the overhanging hopper on the end of the dredge. (See fig. 1.) This clamshell bucket was built by the company from their own patterns and is made of cast steel with lips, pins, sheaves and all wearing parts of manganese steel.

The clamshell holds 40 cubic feet when level full. It is rigged with two 1-inch cables 225 feet long, one a closing line and the other a trip or holding line. The closing mechanism is the same as that of the well-known Williams 2-line clamshell bucket. An ordinary stiffleg derrick is used. The boom is of wood and is 65 feet long with two 30-inch diameter sheaves in the top which lead the cables directly to the hoist through two 18-inch lead blocks swung from the A frame. This method of rigging works well, as the boom seldom travels more than a quarter turn. No turntable is used but pull lines from each side of the boom provide radial movement. The derrick is designed to lift 20 tons and the hoist for a straight pull of 10 tons.

The clamshell discharges into a 12 by 14 foot hopper built of wood. Three sides of the hopper slope and the fourth side is vertical and is fitted with a steel gate 14 inches square which is operated by hand. Material is fed through this gate into a cylindrical trunion-type trommel turning 30 r.p.m. and fitted with ¼-inch mesh wire cloth made of spring steel. This screen dewaters the gravel before discharging it on to the No. 1 conveyor belt. It also removes the sand from the gravel. No extra water is used in this operation.

The No. 1 conveyor belt is level, 30 inches wide, 75 feet between centers and has an average capacity of 200 tons per hour at a speed of 250 f.p.m. It discharges onto a washing table 5 feet long, 3 feet wide, and 18 inches deep extending into the main screen. This washing table sits level and is lined with ¾-inch steel plate bolted to the bottom and sides. The material is broken up and washed from this table into the trommel by a 5-inch stream of water delivering about 600 gallons per minute. In the trommel the material is washed again by a system of jets fed by a 3-inch pipe delivering about 200 gallons per minute against a head of approximately 60 feet. Valves placed at the washing table regulate the amount of water passing through the 5-inch main and the 3-inch jet system. Both are supplied by an 8-inch pump, belt-driven from the main countershaft, as shown in Figure 1. The surplus water from this pump fills the 3-inch fire main and also cools the main Diesel engine. The balance is returned to the river through the drip pans under the conveyor belts.

The main trommel has a standard frame supported on 30 by 5 inch trunion wheels at the charging end and the usual shaft at the discharge end. It is driven by a belt from the main-engine shaft through a bevel gear and pinion at 11 r.p.m. This screen has a slope of 22 inches in its length of 20 feet. It has two jackets. The inside section is 46 inches in diameter and its first 16 feet is of 3/8-inch plate with holes 1-5/8 inches square spaced diagonally across the section. The lower 4 feet is a punched plate with 3-inch round openings. The first jacket, 6 feet in diameter and 16 feet long, is made of 5/16-inch plate with 1-1/8-inch square holes. The second jacket is 8 feet in diameter and 8 feet long and is built in two sections of spring-steel wire with 3/8-inch openings. A screen of this design was used to save space.

The oversize bowlders pass directly from the screen to a 48-inch disk crusher set to crush to 1-inch size and discharging to the No. 1 belt conveyor over the No. 3 conveyor (see fig. 3).

The No. 3 conveyor belt which is 20 inches wide, 58 feet between centers, and travels 250 f.p.m. carries an average of 42 tons per hour. This method of mixing the crushed stone with the gravel makes a uniform and satisfactory product.

Out of 100 tons of material dug by the dredge, about 40 tons will pass the 3/8-inch screen and the dewatering screen. This fine material is usually wasted, but when making sand about 25 tons out of the 40 tons of fines is saved. The 60 tons of material larger than 3/8 inch is screened and crushed to the desired size. When making two sizes of gravel simultaneously, there will be about 25 tons of 3/8 to 1-1/8 inch material and about 35 tons of 1-1/8 to 3 inch gravel in the material larger than 3/8 inch.

The finished material is delivered by conveyor belts to barges alongside. It is possible to load a barge on each side simultaneously, and loading in this way is necessary for paving jobs where the material must be furnished in two sizes.

The No. 2 conveyor belt is 24 inches wide, 54 feet between centers, and travels 225 f.p.m. This belt carries an average of 70 tons of 3/8 to 2 inch finished material per hour to No. 2A conveyor which is a 24-inch belt on 28-foot centers, traveling 225 f.p.m. and discharging to the barges on one side.

The No. 4 conveyor belt is 20 inches wide, 48 feet between centers and travels 225 f.p.m. This belt carries an average of 42 tons of 3/8 to 1 inch finished material per hour directly from the main screen to the barges on the side of the dredge opposite that served by conveyor No. 2A.

The minus 1-1/8-inch plus 3/8-inch material can be delivered to either No. 2 or No. 4 conveyor by shifting a gate in the hopper just below the main screen. This is done in order to eliminate the shifting of barges from one side of the dredge to the other. Figure 3 shows a complete flow sheet of the dredge.

Directly under the sand jacket on the main screen there is a sand settling box of the usual V-shaped type with a gate in each side, one leading overboard and the other to a 16-inch screw conveyor 15 feet long which discharges the settled sand to the No. 4 conveyor and thence to the barge. The waste gate is adjustable to regulate the amount of fines going overboard. The only wash water used is that coming through the main screen. The natural sand is built up, as previously stated, with the fines from the crusher. This system results in a uniform and satisfactory product.

All belts are made of 28-ounce 5-ply duck and have 1/8-rubber cover and 1/16-inch rubber back. All conveyor rolls are ball-bearing and all conveyors are fitted with drip pans continually flushed with water to carry the spill back to the river. The conveyors are driven from the main engine through shafts and pulleys by rubber belts. The power is furnished by a 4-cylinder full Diesel engine, 14-inch bore and 17-inch stroke, developing 240-hp. at 257 r.p.m. and mounted on a foundation of steel beams and concrete. This power plant is serviced by a 10-hp. auxiliary engine driving the usual air compressor, oil and water pumps, and generator. The hoisting machinery, anchor winches, barge winches and clutches were all built locally from designs furnished by the company.

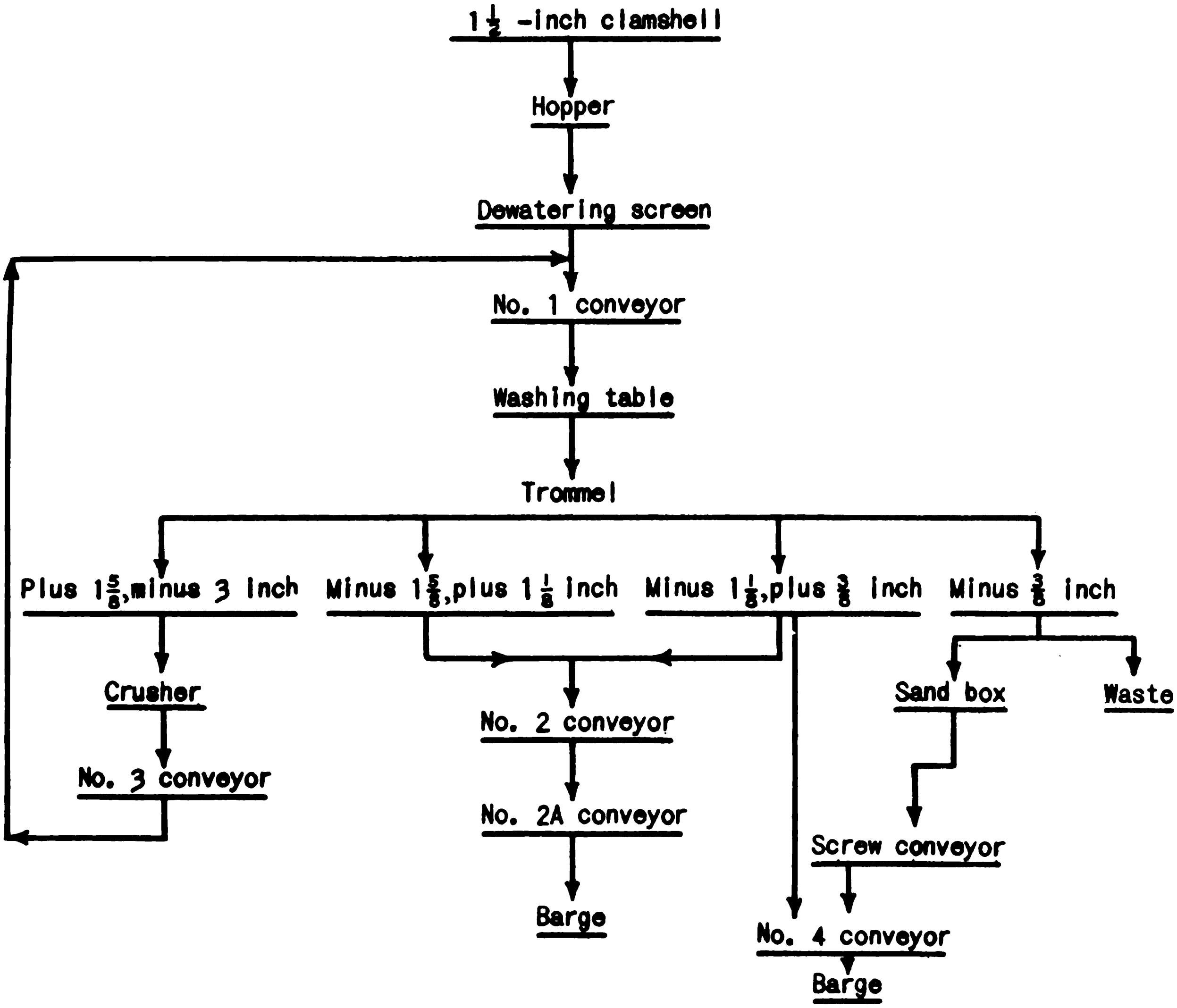


Figure 3.- Flow sheet of the dredge "Boulder"

The dredge hull is of wood and is 117 feet long, 32 feet wide and 6½ feet deep. No spuds are used but the dredge is held by four anchors, one at each corner to permit movement in any direction.

There is a 4-inch fire and barge pump that can be driven from either the main or auxiliary engine.

The average capacity of this dredge is 50 cubic yards per hour.

Living quarters for the crew are provided on the upper deck of the dredge.

The barges have a capacity of 300 to 500 cubic yards and are all built of wood.

DREDGING SAND

Dredge "Sandy"

The "Sandy" is a suction dredge with a wooden hull 90 feet long, 30 feet wide and 5 feet deep. The sand pump has a 10-inch suction and a 12-inch discharge. The impeller has three ports and is 28 inches in diameter. It is the closed type and is made of carbon steel. The pump housing is cast iron with a cast-iron liner on each side of the impeller. The main pump housing is replaced when worn, as this is cheaper than relining while dredging this kind of material. This pump makes 410 r.p.m. and operates against a head of 22 feet.

The main engine is a 75-hp., 2-cylinder semi-Diesel of 12-inch bore and 15-inch stroke, and makes 300 r.p.m. It is set on steel I beams which extend far enough to hold an outboard bearing which supports a tail shaft and a clutch pulley. There is another pulley on this shaft which drives the anchor machinery through a second clutch pulley.

A 3-hp. gas engine furnishes auxiliary power for the generator and air compressor. A 3-inch fire and barge pump is driven from the main engine.

The sand pump is driven by a belt from the main engine through a clutch to permit flushing out the pump.

There are two forward anchors on this dredge. No spuds are used as the current in the river holds the dredge in position. There are also three live drums attached to the anchor winches for moving barges alongside. These winches were built locally to fit the conditions and are driven from the main engine through clutches, as is also a small 2-drum winch that hoists the suction pipe.

The suction pipe line is made up of two 20-foot lengths of standard 10-inch pipe welded end to end and stiffened by three T irons welded at equally spaced intervals around this pipe and extending 10 feet along each section. A suction nozzle made of welded plate with a suitable screen over the end completes the suction line. This is connected to the main pump by a swivel joint and rubber suction sleeve to permit the pipe to swing vertically. The suction line hangs over one side of the hull on two davits. A cutter or agitator is not needed as the sand is loose. The pump handles from 18 to 20 per cent solids.

The sand pump discharges into a stationary cylindrical screen built up of three sections each having a different size of screen and covering one-third the circumference of the cylinder. The screen is mounted over a deep wooden flume. When in operation the screen is stationary and the bottom section is the only part in use. In changing sizes, the screen is turned so that the proper screen is at the bottom and the whole is then locked in position.

The oversize from this screen is rejected over the stern of the dredge. The sand drops through the screen into a deep flume, which can be raised or lowered, and is delivered to the barges alongside. About 20 per cent of the material pumped is wasted back into the river. The average capacity of this dredge is 175 cubic yards per hour.

To obtain different grades of sand it is only necessary to move the dredge to different sand bars.

Living quarters are provided on the dredge for the crew.

The barges loaded at this dredge all have sand boxes built on them fitted with sliding steel gates. These gates are at the bottom of the box at the deck level. The flume from the dredge extends across the barge and loading is started at one end and continued to the other, the water being forced through the gates by the sand. The gates are raised as the sand fills the boxes.

DIFFERENCE IN COST OF PRODUCING GRAVEL AND SAND

The cost of producing gravel is much higher than that of pumping sand, for the following reasons: The volume produced is considerably smaller, the gravel deposits are much more difficult to work, the maintenance on machinery is much higher, the cost of crushing is added, the power cost is higher, and the labor cost is twice as much.

The operation of pumping sand is simple and there are practically no interruptions, as the Columbia River deposits are clean and the percentage of waste material is fairly low.

The personnel and wage rates are as shown. All crews board themselves.

Personnel and wage rates

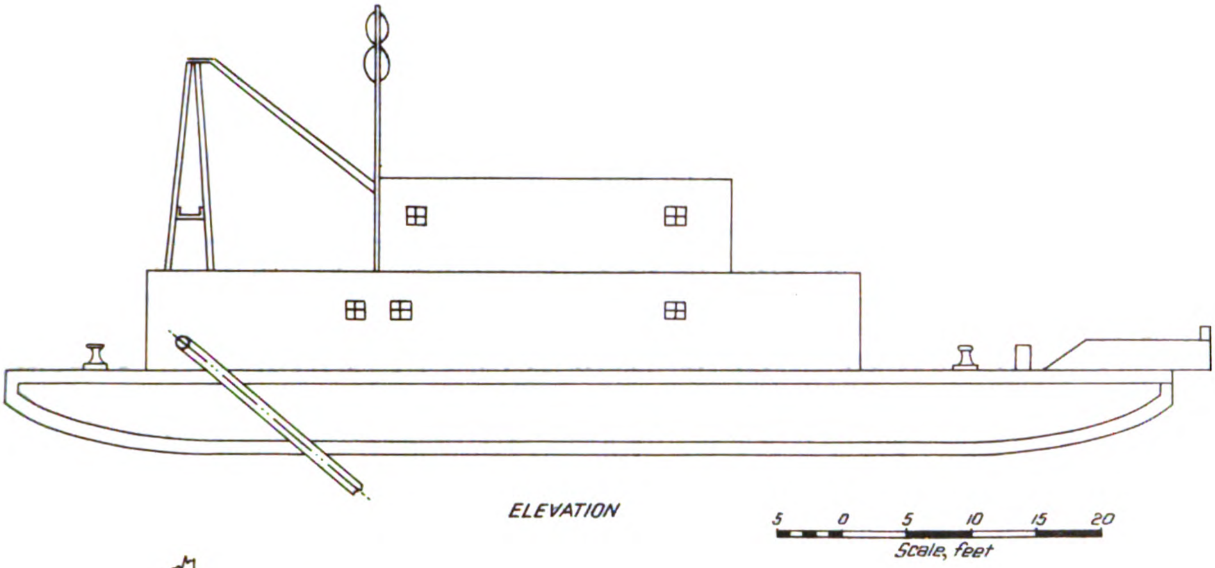
	Per day	Per month
Dredge "Boulder":		
Foreman		$175
Clamshell operator		175
Hopper man	$4	
Bargeman and watchman	5	
Dredge "Sandy":		
Foreman and operator		175
Bargeman and watchman		100

Table 1.- Cost of producing gravel

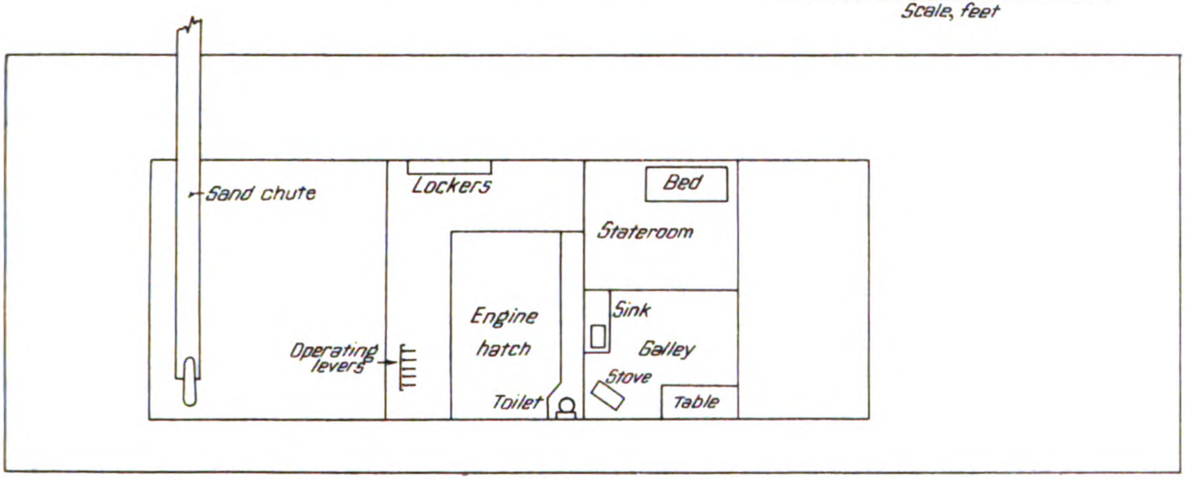
Dredge "Boulder" Period covered, January 1 to December 31, 1929.

Tons gravel produced, 84,000.

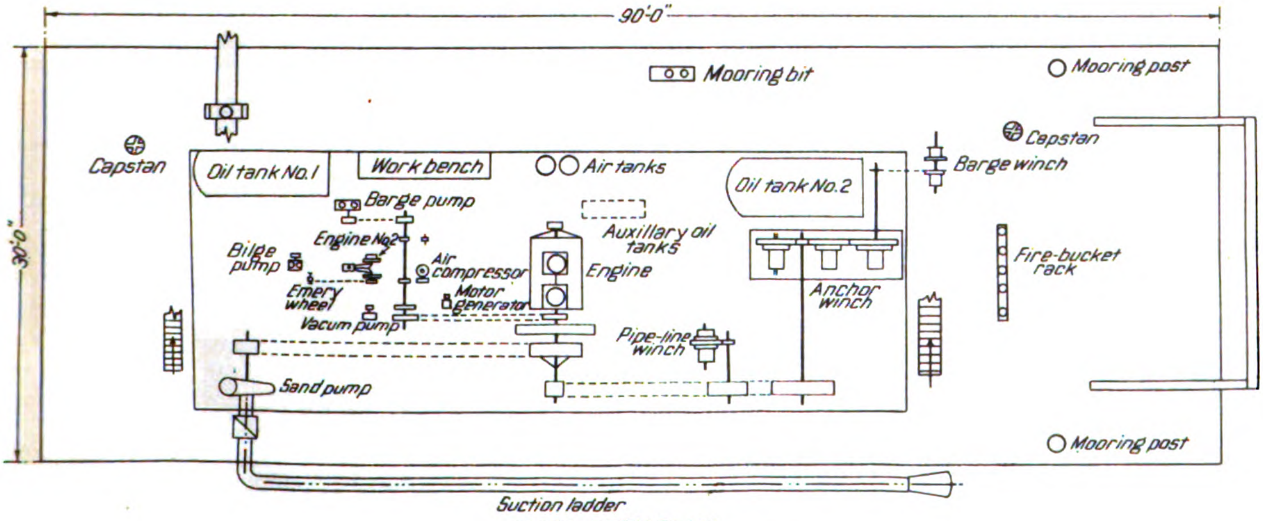
	Cost per ton
Power, including labor, repairs, fuel, oil, etc.	$0.0520
Clamshell derrick, including labor, repairs, cables, oil, etc.	.0292
Conveyors, including labor, repairs, oil, etc.	.0172
Screening, including labor, repairs, etc.	.0240
Curshing, including labor, repairs, oil, etc.	.0378
Miscellaneous operation, including salaries, superintendence, miscellaneous repairs, etc.	.0480
Royalty	.0600
Depreciation	.0690
Total operating cost	$0.3372



ELEVATION



UPPER-DECK PLAN



MAIN-DECK PLAN

Figure 2.-Side elevation and deck plans of dredge "Sandy"

Table 2.- Cost of producing sand

Dredge "Sandy" Period covered, January 1 to December 31, 1929.

Tons produced, 126,500.

	Cost per ton
Power, including repairs, fuel, oil, etc.	$0.0080
Pumping, including pump repairs, parts, oil, etc.	.0132
Miscellaneous, including all labor, repairs, oils, cables, flume repairs, etc.	.0570
Royalty	.0437
Depreciation	.0220
Total operating cost	$0.1439